



Measurement of Dust Production in Active Comets

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Abstract:

Dust production varies greatly from comet to comet, although the causes of these differences are not well understood. Temporal variations in dust production indicate dynamical changes within the comet nucleus, giving key insight into the evolution of the comet as a whole. We present 2011 and 2012 R-band observations of three active comets known for their differing dust production characteristics: low-activity 49P/Arend-Rigaux, high-activity C/2009 P1 (Garradd), and outburst-prone 29P/Schwassmann-Wachmann. Using narrowband photometry, we measure their dust production in terms of Afp and examine how it changes with time. Multi-aperture measurements of Afp also yield qualitative information about the comet's spatial dust profile, and variations in these profiles are studied as well.

Introduction

Comets are identified by the significant amount of dust they eject into space, which forms their characteristic tail-like structures. It is accepted this dust is produced by the sublimation of volatiles such as water ice from their nucleus. The level of dust activity is observed to differ significantly between comets, a consequence of the wide range orbital paths and nucleus structure/compositions within the comet population, and often is not well understood.

The dust production of an individual comet varies over time, often due to its changing solar distance. Studying these variations yield insight to the dynamic processes that affect comet activity. We monitor three unique comets in order to better understand their dust production:



49P/Arend-Rigaux



29P/Schwassmann-Wachmann 1



C/2009 P1 (Garradd)

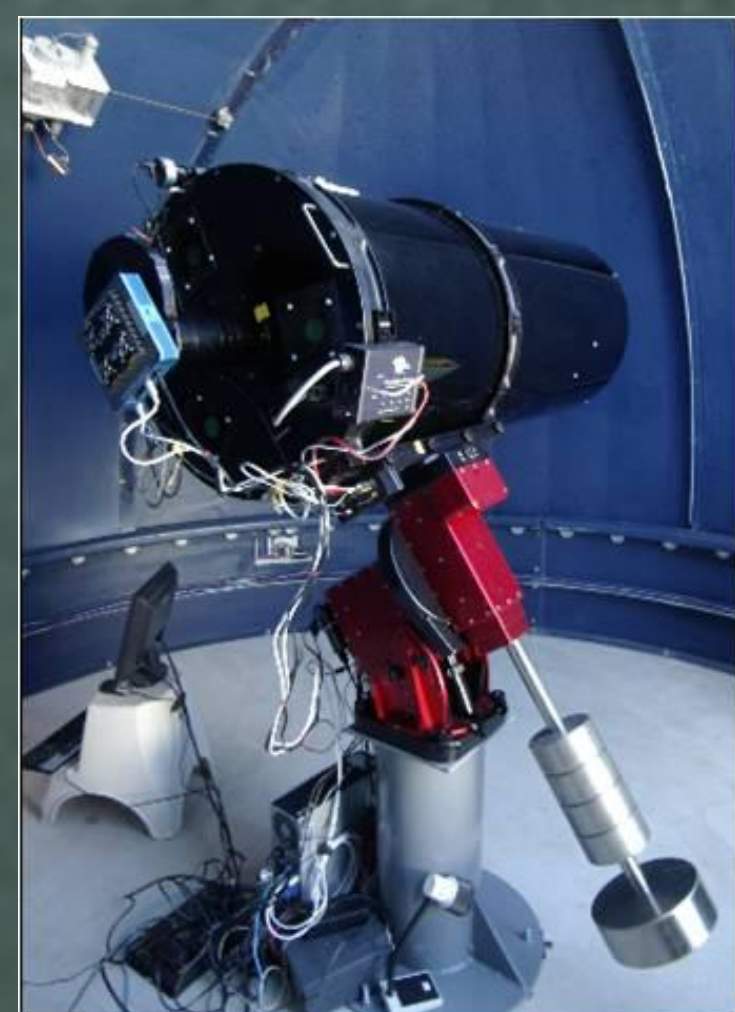
Method

We determine the dust production by calculating Afp, which is the product of the object's albedo (A), filling factor of grains within the field of view (f), and measurement aperture size (p)^[1]. The advantage of Afp is that it makes no assumptions about the dust characteristics of the comet (such as grain size or velocity, often unknown), and can be calculated explicitly from its observed brightness:

$$Afp = \frac{4\Delta^2 R^2}{\rho} * \frac{F_{com}}{F_{\odot}}$$

Where Δ = earth-comet distance, R = sun-comet distance, F_{com} = observed flux of the comet, and F_{\odot} = the flux of the sun at 1 AU. The brightness is measured through multi-aperture photometry, in which the comet signal is summed within differently sized measurement apertures placed over the object. This signal is converted to a flux by comparing it to the signals of nearby field stars of known brightness. How Afp changes with aperture size characterizes the spatial brightness profile of the dust (proportional to ρ^γ), as well.

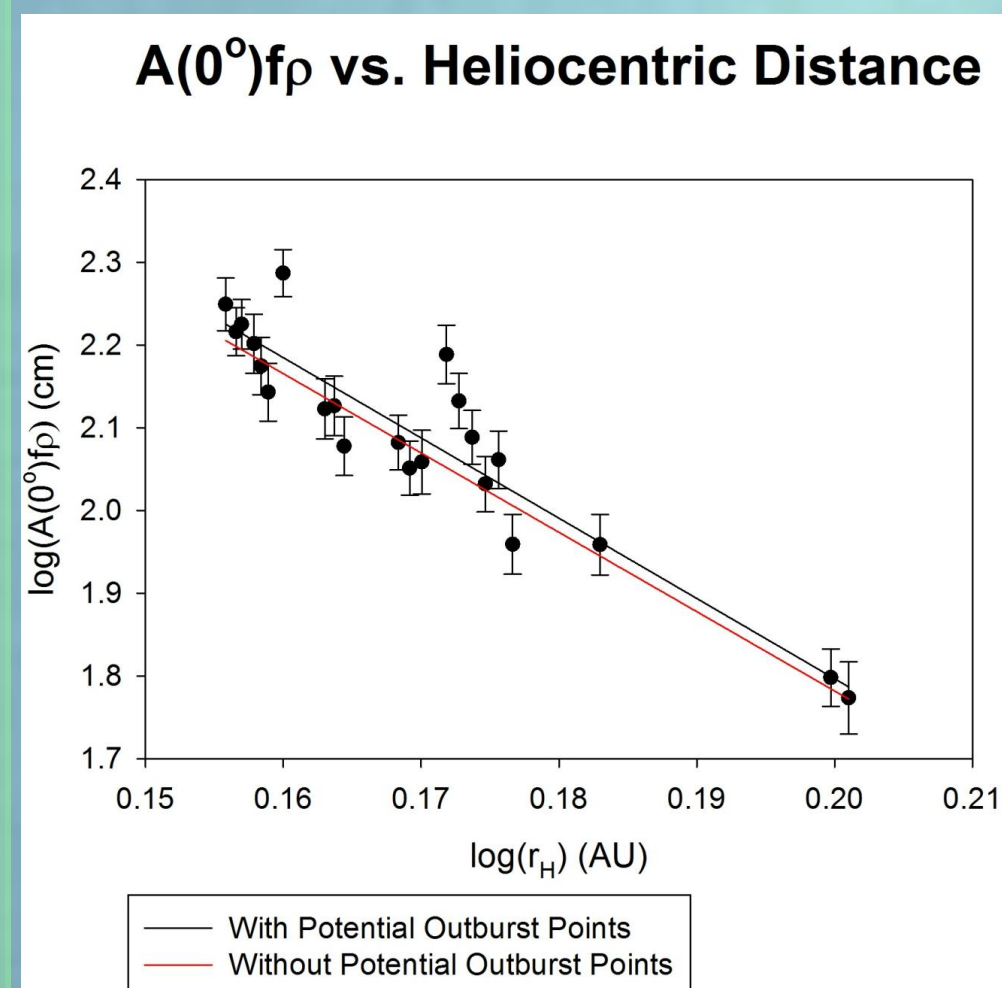
Comet observations were obtained using a 20-inch telescope with an Apogee U9000 camera, using 180 second exposures through a Johnson R filter. The telescope is located near Mayhill, NM, and is operated remotely from MSFC. We use the software programs *Astrometrica*^[2] and *FoCas*^[3] to do the aperture photometry. Observed fluxes are derived using 10, 20, 30, 40, and 50 arc-second (") apertures.



Results

Comet 49P/Arend-Rigaux: Asteroid-Comet Transition Object?

This object is known for its extremely low dust production, and is thought to be transitioning from comet to asteroid^[4]. We observed it from November-December 2011, right after perihelion, as it was 1.43-1.53 AU from the sun. Due to the comet's small angular size, only measurements from 10" aperture are reported.



➤ **Steady reduction in Afp with solar distance (r_H):**

$$\text{Log}(Afp) = (3.7 \pm 0.08) - (9.6 \pm 0.5) \log(r_H)$$

➤ Predicted Afp at perihelion ($r_H=1.42$ AU): **169 +/- 15 cm**

➤ Predicted extinction of dust production at $r_H = 2.43 \pm 0.14$ AU

➤ Small outbursts potentially observed at $\log(r_H) = 0.16$ and 0.171 , but does not have significant effect on linear fit

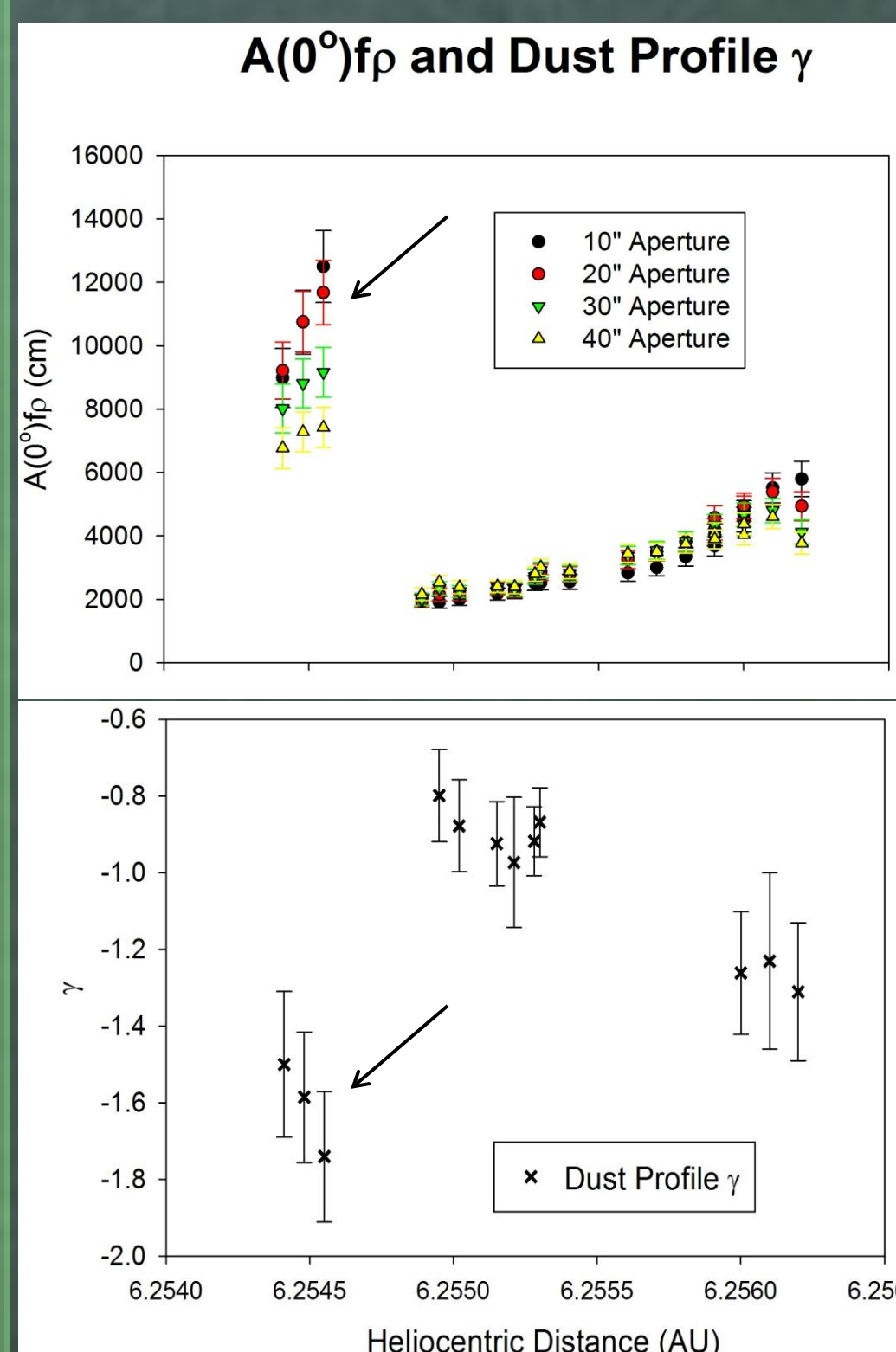
Comet 29P/Schwassmann-Wachmann 1: Mysterious Outburster

Comet 29P has been observed to exhibit abrupt increases in brightness (and thus dust production) called "outbursts" at a frequency of ~7.4 times/year with an average separation of 50 days^[5]. This highly active behavior is puzzling given the object's large solar distance (~6 AU).



We observed **two outburst events:**

- 5/01/2011 – 5/03/2011
- 6/26/2012 – 7/01/2012



➤ Left: Afp and dust profile slope γ for June-July 2012 observations, showing outburst (time goes right to left)

➤ **Dramatic increase in Afp:**

- 2011: 1949 +/- 198 cm to 12494 +/- 1139 cm
- 2012: 2668 +/- 254 cm to 19595 +/- 1448 cm

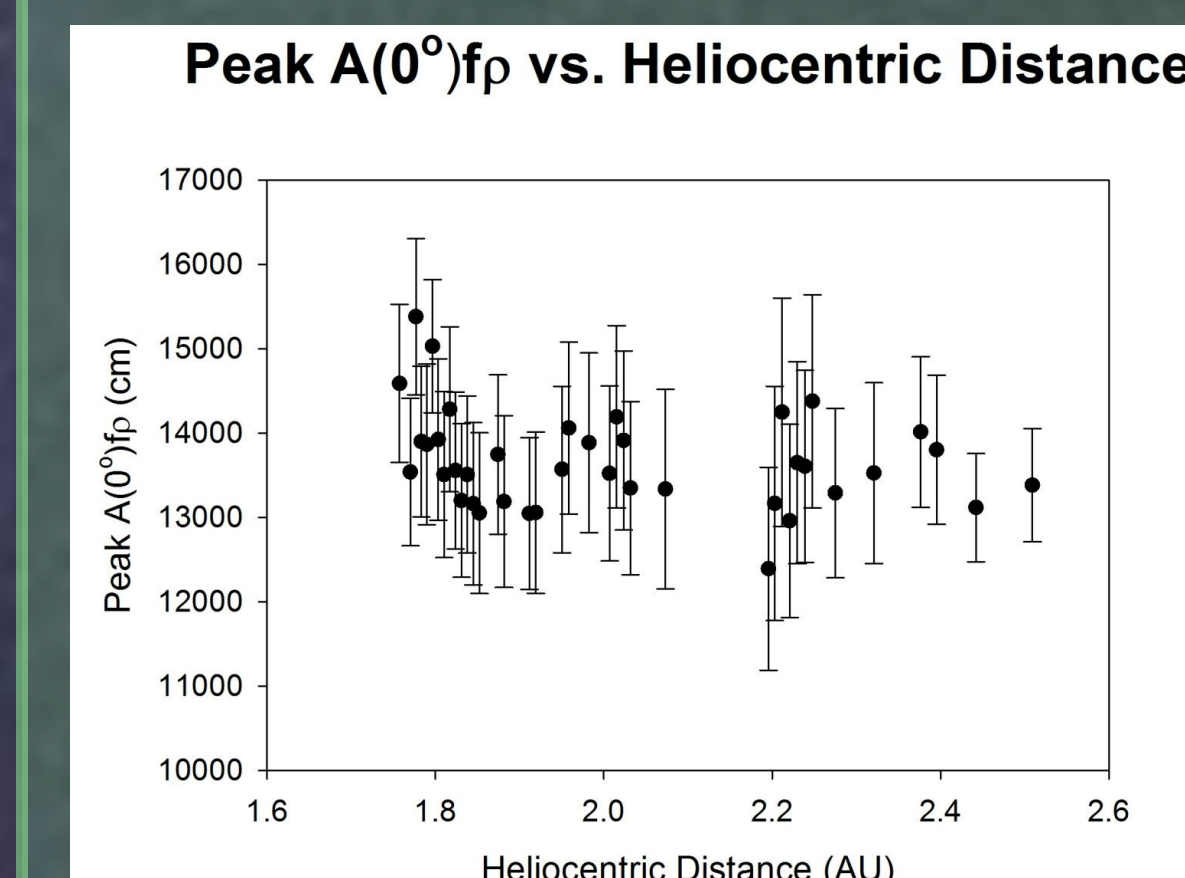
➤ **Newly released dust** near nucleus caused profile slope to shift from $\gamma \sim -1$ (quiescent) to $\gamma \sim -1.65$ during outbursts

➤ With dust properties modeled^[6], we can calculate the **dust production rate:**

- 2011: 22.3 +/- 7.7 kg/s to 491.2 +/- 166.1 kg/s
- 2012: 16.3 +/- 5.3 kg/s to 313.9 +/- 107.4 kg/s

Comet C/2009 P1 (Garradd): High Activity

This bright comet exhibited high dust activity as it approached the sun in 2011. We observed it from August to October 2011, as it traveled at heliocentric distances of 2.5-1.8 AU. Afp values were obtained from the peak of the fitted dust spatial profile, which ranged from $\rho = 1.4 - 2.6 \times 10^4$ km.



➤ Larger uncertainty due to crowded star field

➤ Dust production mainly constant at **Afp = ~14,000 cm**

➤ **Little variation with solar distance**

Conclusions

Comet 49P/Arend-Rigaux: The dust production of this low-activity comet was found to steadily decrease with heliocentric distance, indicating that it is in a quiescent (non-outbursting) state. Observations $r_H > 2.4$ AU have the potential to observe the object's transition into an inactive state, if its dust behavior does not change.

Comet 29P/ Schwassmann-Wachmann 1: Two outburst events are observed, during which Afp is found to increase by a factor of 6-7. This corresponds to an initial increase in dust production rate by a factor of ~20 and remains at elevated levels for at least the following 3-5 days. If representative of 29P outbursts, this data suggests that a significant portion of the total dust ejected by this comet originates from outbursts.

Comet C/2009 P1 (Garradd): Highly active, the dust production of this comet remained fairly constant despite its changing heliocentric distance, suggesting unusual dust activity. Additional observations and higher-accuracy measurements are needed to examine this behavior.

Future Work

➤ Continue monitoring dust production of 29P and other comets, especially during outbursts. Does the majority of the dust get ejected during outburst or quiescent activity?

➤ Use these methods to study dust production of meteor-shower parent comets, in order to better forecast meteor activity

References

- ^[1]A'Hearn et al. (1984). "Comet Bowell 1980b." *ApJ*, 89, pp. 579-591.
- ^[2]<http://www.astrometrica.at>
- ^[3]<http://www.astrosurf.com/cometas-obs/ArtSoftUtil/Focas/FocasCast.htm>
- ^[4]Marsden, B.G. (1970). "On the Relationship Between Comets and Minor Planets." *ApJ*, 75, pp. 206-217.
- ^[5]Trigo-Rodriguez, et al. (2010). "Outburst activity in Comets-II. A Multiband Photometric Monitoring of Comet 29P/Schwassmann-Wachmann 1." *MNRAS*, 409, pp.1682-1690.
- ^[6]Ivanova et al. (2011). "Observations of the Long-Lasting Activity of Distant Comets." *Icarus*, 211, pp. 559-567.